IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s):	Walter Musial, et al.	)	Group Art: 2857
		)	
Serial No. :	10/520,011	)	Examiner: GUTIERREZ, Anthony
		)	
Filed:	December 29, 2004	)	Atty. Dkt. No. NREL 01-51
		)	
Title:	Resonance Test System	)	

DECLARATION UNDER 37 C.F.R. §1.131

To: Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

I declare:

1. This declaration is being made in support of allowance of claims 1-21 in the above-identified patent application (the "invention").

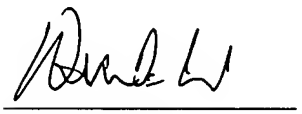
2. I am the lead inventor and a co-inventor of each claim of the invention that this declaration is being made in support of.

3. Each of the acts described herein was undertaken in the United States.

4. I, along with my co-inventor, conceived of the invention and reduced the invention to practice prior to June 6, 2001. See Exhibit A, which is a record of invention and related reports prepared in the normal course of business to describe the invention. The record of invention is signed by myself and each of my co-inventors. The laboratory notebook is signed by my co-inventor Darris White and witnessed. The redacted dates are all prior to June 6, 2001.

5. The patent application was filed by the National Renewable Energy Laboratory (operated by Midwest Research Institute for the U.S. Department of Energy) on December 29, 2004, as evidenced by the U.S. Patent Office filing date accorded this patent application, and claims priority to PCT Patent Application No. PCT/US02/20991 filed July 3, 2002.

6. I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.



Walter Musial

Dated this 02 day of July 2008.

EXHIBIT A

NO B+R #

U.S. DEPARTMENT OF ENERGY
OFFICE OF ASSISTANT GENERAL COUNSEL FOR PATENTS
RECORD OF INVENTION

NREL IR No. 01-51

This Record of Invention is an important legal document and proper care in its early and complete preparation will save important time and inconvenience in the future. The Instructions* on the back should be read carefully before filling in the data.

A. Inventor: 1. Name(s): Walter Musial, Darris White

2. Title or Position: Senior Engineer II, Summer Intern

3. Employed by: National Wind Technology Center

4. Permanent Address: 194 Meadowlook Way, Boulder, CO 80304
1475 Folsom St Apt 1005, Boulder, CO 80303

B. Title of Invention(1*): Resonance Test System for Wind Turbine Blades Using Hydraulic Excitation.

C. Description of Invention (2*):

1. This invention uses hydraulic actuators to excite the fundamental flap frequency of wind turbine blades. The actuator accelerates a given mass harmonically to generate the input force for the test. The magnitude of the input force is controlled by the actuator stroke. Additional masses are added to the test blade to provide the desired stress profile and mode shape. This test method has several advantages over the method previously used. The energy required to test the blade has been significantly reduced and the system requires less hydraulic flow. The duration of the test depends primarily on the fundamental frequency of the loaded blade not the oil flow capacity. This will generally require less test time than the conventional test for blades requiring large displacements (i.e. blades greater than 30 meters in length). Another advantage to this test method is that more of the blade can be tested. The shape of the stress profile for the Resonance Test System produces some stress near the tip of the blade that can not be accurately produced using the previous test method.
2. Edge loading will be applied in conjunction with the resonant flap excitation using constant amplitude forced displacement loading at a single spanwise point. The edge force will be delivered at the same cycle frequency as the resonant flap actuator system described in part 1 above. This system overcomes the major shortcoming of previous resonance blade testing by allowing the edge load to be applied simultaneously with the flap test. This also allows a net decrease in the total test time because the edge test does not have to be done separately.

D. Dates and Places of Inventions:

1. Conception by Inventor (3*) [redacted] At NWTC, Golden, CO

2. First Sketch or Drawing [redacted] At NWTC, Golden, CO In Workbook None Page _

3. First Written Description [redacted] At NWTC, Golden, CO In Workbook None Page _

4. Disclosure to Others (4*) _____ At _____

a. [signature] 7/11/2001 At NWTC (Scott Hughes)

b. [signature] 7/16/01 2001 At NWTC (Sandy Butterfield)

5. Completion of Model or Full Size Device June 27, 2001 At NWTC, Golden, CO

6. First Test or Operation of Invention _____ At _____

E. Results of Tests and Extent of Use of Invention (5*)
Models indicate that the Resonant Test System will reduce the peak hydraulic flow rate from 370 GPM to 147 GPM and could reduce testing time from 70 days to 45 days for 34m long blade.

F. Names of all persons having knowledge of facts stated under D and E: Walter Musial, Darris White, Scott Hughes, Sandy Butterfield, Bob Threasher.

G. Pertinent Reports (6*):

H. Other Closely Related Publications, Patents, and Patent Applications (7*):

I. Rights of U.S. Government:

J. Licenses or Assignments:

K. Contracts Involved:

Contract No.: Date:

Subtask No.: 5000-2000 Date: [redacted]

Contractor and Address

Type of Contract:

(Unclassified) | Restricted | Confidential | Secret

L. Signature of Witness: Cynthia Bzydlik Date: 7-11-01

Signature of Inventor(s): [signature] Date: 7/11/01

[signature] 7/11/01

Forwarded by (8*): Date:

(OVER) Rev. 11/8/93

Received
SEP 05 2001
Legal Office

Darris White
Research Assignment

Project Subtask: 5000-2000
Project Leader: Walt Musial
[redacted]

Design and Analysis of a Resonance Testing System for Wind Turbine Blades Using a Servo-Hydraulic Excitation.

Background:

The structural testing facilities at the National Renewable Energy Laboratory are the only ones in the U.S. where full scale testing of large MW class wind turbine blades can be conducted. The laboratory facilities, located at the National Wind Technology Center (NWTC), have been in operation since 1989 and are internationally recognized and accredited by A2LA. The capabilities include static testing and fatigue testing. Static tests are designed to test the blades ability to withstand extreme load conditions under a single load application, while fatigue tests are designed to validate the operational lifetime of the blade under repeated damage-equivalent loading. The structural test facilities use a state-of-the-art servo-hydraulic system that applies the flap and edge loading to the blade at a single span of the blade. The loads are computed to deliver a full life of operation in a fraction of the design life by accelerating the fatigue damage caused by a single cycle two or more orders of magnitude. Typical tests run 1 to 5 million cycles. The amount of oil that can be pumped through the actuators and the number of cycles in the test determine the speed at which a test can be run. As blade size has increased, the demand for larger actuators with higher loads and longer strokes have in turn led to larger oil pump requirements in order to complete tests in a reasonable time frame. Such escalation is in progress at the NWTC where the current pump capacity is being upgraded from 150 GPM to 280 GPM.

In Denmark, other blade testing methods have been used that appear to have merit for some applications. Almost exclusively, the Danes have employed resonance testing as their primary means for testing blades. In resonance testing, the blade is excited at its natural frequency and the amplitudes and strain levels are controlled for blade fatigue tests of any size. In Denmark, the excitation method has been limited to using an eccentric mass (200-500 Kg) rotating on a shaft with a variable speed drive (30 - 90 rpm) to control the amplitude of vibration. This method is simple but it works. The Danes have been using this technique for over 15 years and have worked out most of their control problems.

The advantages of resonance testing are:

1. The blade typically can be cycled faster,
2. The blade can be excised over its entire span,
3. The energy required to conduct a test much lower,
4. The lab space required to conduct a test is much less, and
5. It appears the cost of the equipment (especially for large blades) is lower.

The disadvantages of resonance testing are:

1. The loads cannot be applied accurately because biaxial load combinations are not possible and,
2. The load distribution is not known explicitly and must be inferred from analysis or static testing.

Although the advantages outweigh the disadvantages, the accuracy of testing with hydraulic actuators is still the preferred method. Both types of testing are allowed under IEC 61400-23 and it seems that both may have merit in their own right.

At NREL, the testing of large blades is limited to a single test bay, which is sometimes occupied for up to six months with a single blade test. The demand for testing has continued to grow and faster and more efficient testing methods may be necessary to meet the demand over the next few years. Therefore, we would like to investigate a lower cost, higher speed test method such as resonance testing.

Overall Research Objective

Design, develop, and build a resonance testing system that can be used in the 4th quarter of 2001 to test large wind turbine blades at the NWTC using existing servo-hydraulic equipment.

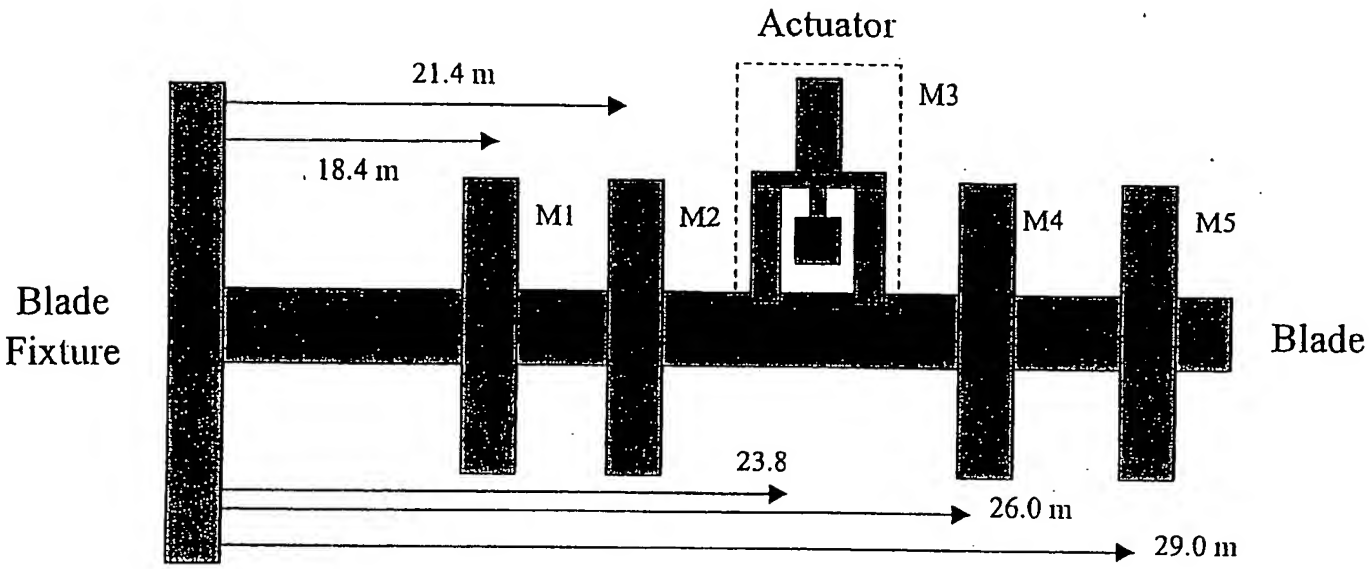
Servo-Hydraulic Resonance Testing:

The advantage that NREL would have in the development of a resonance testing capability is that the capital investments have already been made. We should be able to leapfrog over the development of a Danish type system by taking advantage of our expertise in hydraulics and hydraulic controls. We would also be the only laboratory capable of testing to either method. The Danish method of swinging an eccentric mass will be replaced by existing servo-hydraulic equipment at NREL. Relatively small actuators mounted on a blade can be used to move masses at the blade's natural frequencies. Control may be possible by varying frequency within the MTS Flextest control system, or more likely by varying the actuator stoke at a fixed frequency. Closed loop feedback can be obtained from blade mounted strain gages or from another sensor provided by NREL.

The research assignment is broken into the following elements:

- Develop a conceptual design for a closed-loop servo hydraulic system capable of testing blade from 30 – 50 meters in length using existing NWTC equipment.
- Investigate the best method for controlling blade motion including frequency or displacement control, and various feedback options (e.g. strain, displacement, and load).
- Investigate methods and define a procedure to determine and validate the actual load distribution.
- Develop a one-dimensional dynamic simulation of this system.
- Work with NWTC engineers to develop a detailed design of the hardware required to mount the actuator, the oscillating masses, and the mounting frame.
- Procure the parts necessary to build the resonance testing system.
- Assist in building the system.

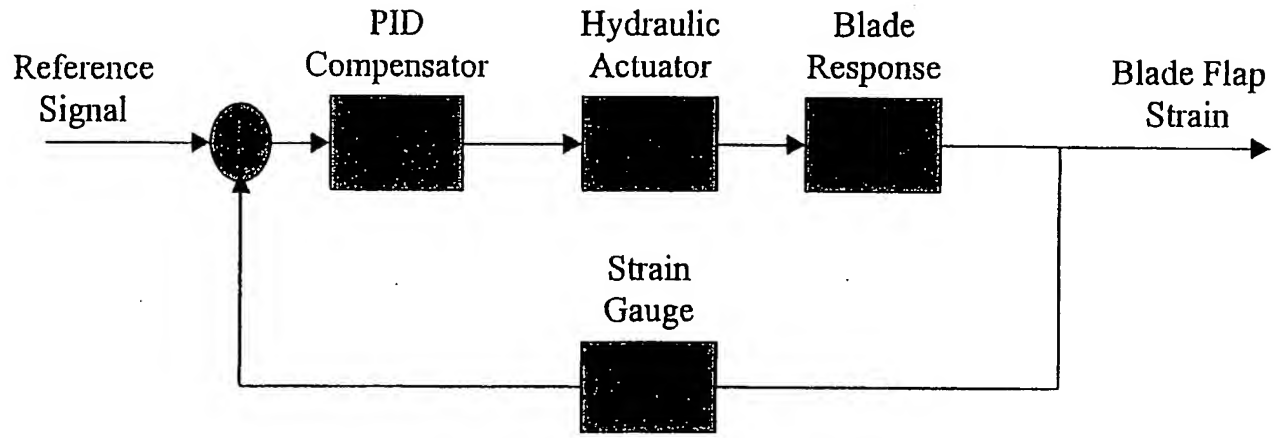
If appropriate, submit a report or package for each of the bullets above. Feel free to discuss any of the work outlined above with your task leader and/or modify the items with his mutual consent.



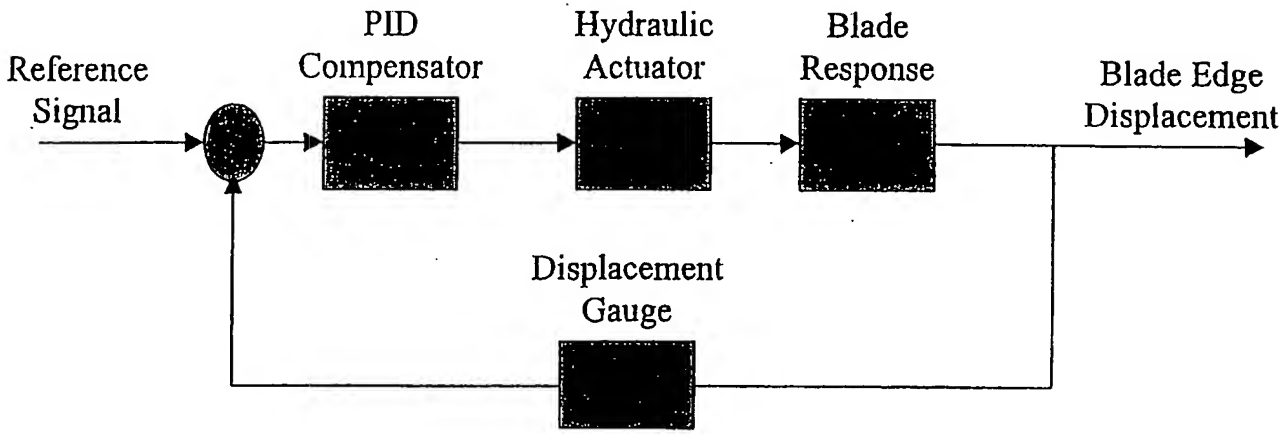
Mi	Mass, kg
M1	493
M2	370
M3	700
M4	185
M5	62

Mass Distribution for Resonance Testing System of EW34a Blade

Flap Actuator



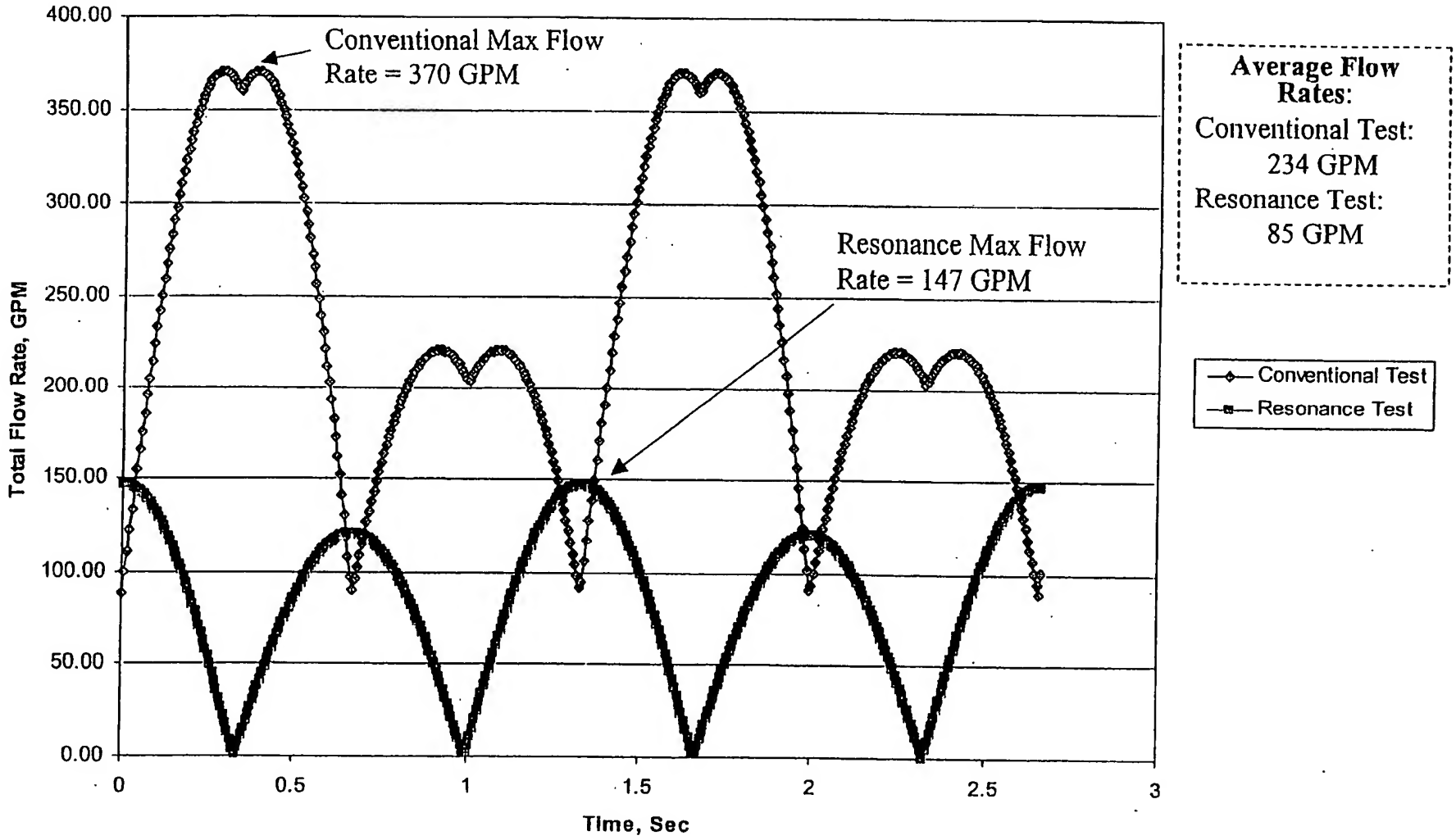
Edge Actuator

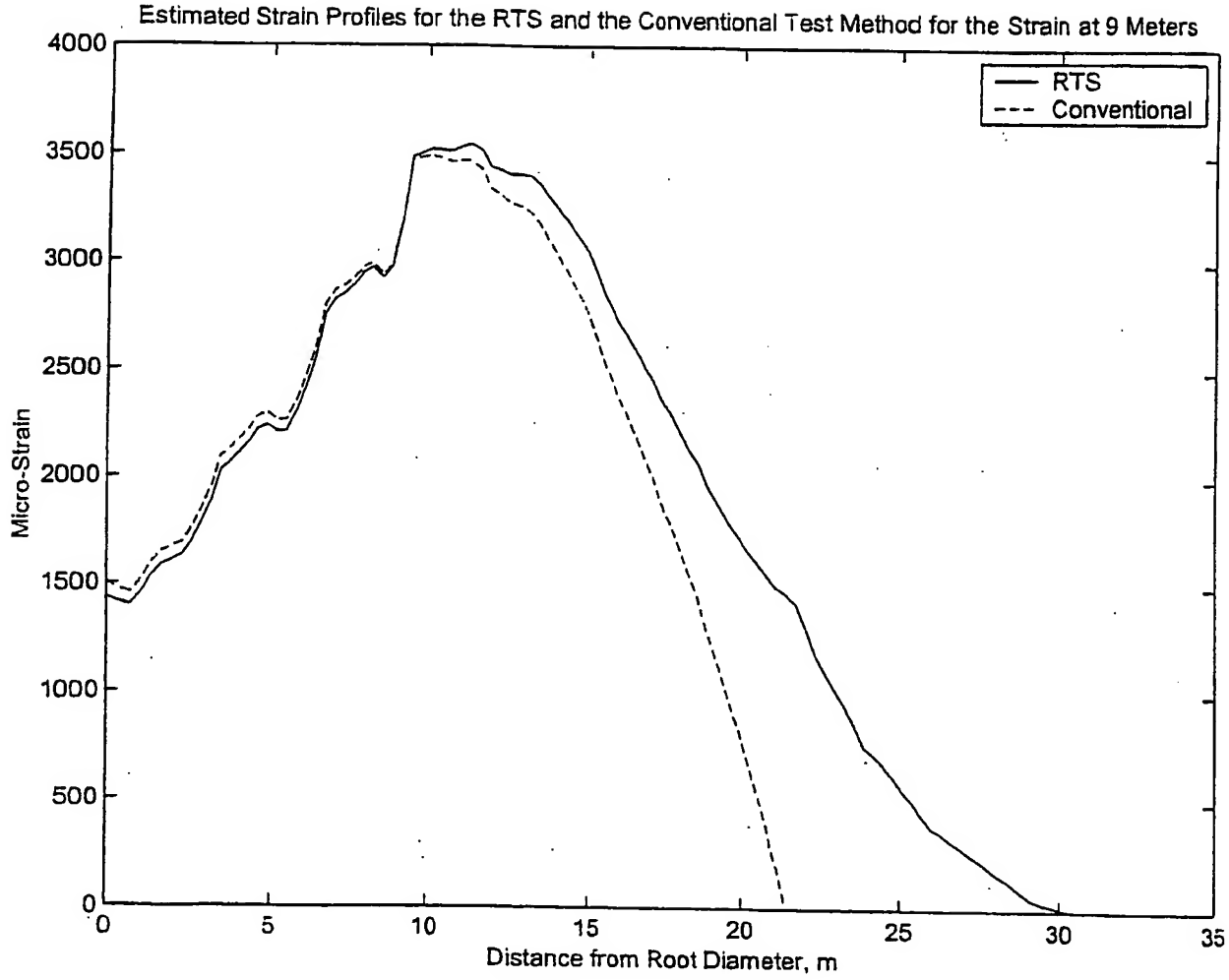


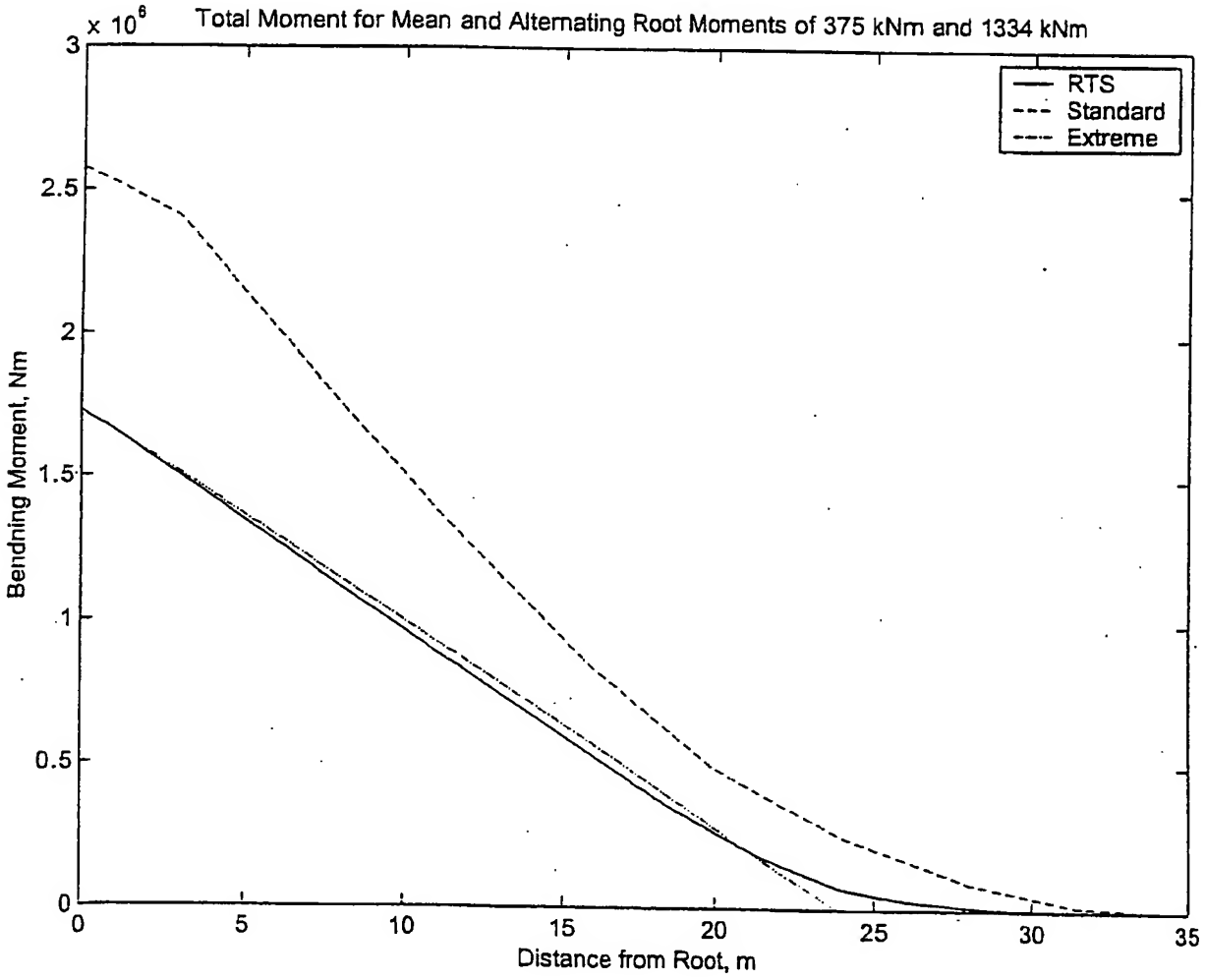
Definition of Controls Blocks

- PID Controller - Software Algorithm used to improve system response
- Hydraulic Actuator - Transfer Function Between the Electric Signal to the Actuator and the Actuator Response
- Blade Response -Transfer Function Between the Force Applied by the Actuator and the Blade Response (Flap and Edge Transfer Function will be Significantly Different).
- Feedback Gauge - Either Displacement or Strain may be used as Feedback for the Control Algorithms

Total Flow Rate Required to Excite the EW34a Blade at 0.75 Hz in Both the Edge and Flap Directions for the Conventional Test Method and the Resonance Test Method




Estimated Strain Profiles for the RTS and the Conventional Test Method for the Strain at 9 Meters
RTS
Conventional
Micro-Strain
Distance from Root Diameter, m
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35


Total Moment for Mean and Alternating Root Moments of 375 kNm and 1334 kNm
x 10^6
Bending Moment, Nm
Distance from Root, m
RTS
Standard
Extreme
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35